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COLONY INHABITATION OF WEAVER ANT, *OECOPHYLLA SMARAGDINA* FABRICIUS (HYMENOPTERA: FORMICIDAE) IN DIFFERENT PLANT HOSTS AND THEIR IMPACT ON THE YIELDS OF SELECTED HORTICULTURAL CROPS

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Abstract

The weaver ant is effective as a biological control agent of many pests in different horticultural crops. A survey was conducted to assess the colony inhabitation of weaver ant, *Oecophylla smaragdina* in different plant hosts and their impact on the yields of selected horticultural crops in Faculty of Agriculture, Annamalai University, Annamalainagar, Tamil Nadu. Colony inhabitation of *O. smaragdina* was found in seventeen plant hosts under fourteen families viz., Annonaceae, Meliaceae, Myrtaceae, Fabaceae, Rubiaceae, Moraceae, Rosaceae, Anacardiaceae, Sapotaceae, Poaceae, Malvaceae, Rutaceae, Lecythidaceae, Cucurbitaceae and one unidentified hosts. New record of a creeper plant host, *Coccinia indica* was recorded from India. Fifty four plants devoid of *O. smaragdina* were also identified. Colony inhabitation of *O. smaragdina* occurred in *Mangifera indica* as highest for all the twelve months. In *Morinda citrifolia*, *Manilkora zapota*, *Prunus dulcis* and *Citrus limon* months of occupancy of *O. smaragdina* were ten, nine, eight and six respectively. Coleopterans and Lepidopterans were well controlled by *O. smaragdina* in trees with ant nests in *Mangifera indica*. Homopteran levels were highest than other arthropods in trees with ant nest. The yields of *Mangifera indica*, *Manilkara sapota*, *Citrus limon* and *Anacardium occidentale* were 43.64, 73.16, 1.00 and 22.28 Kgs per tree respectively in the presence of *O. smaragdina* nests whereas in trees without ant nest the yields were 36.08, 65.28, 0.80 and 19.60 Kgs per tree respectively.

***Keywords*:** *Oecophylla smaragdina*, new plant host record, arthropods, yield, horticultural crops

Introduction

Weaver ants are distributed as an arboreal and play an important role in rainforest ecosystems as a keystone predator of small animals, establishing aggressive and territorial colonies that sometimes dominate a wide range across forest canopies. *Oecophylla smaragdina* is widespread from southern Asia to northern Australia, including many tropical western Pacific islands (Azuma *et al*., 2006). Predatory weaver ant is native to Asia and they also recorded that host plant of 175 plant species in 46 families, with 28 associated trophobiont species in 7 families (Lim *et al.*, 2008).

Santos *et al*. (2016) observed that the weaver ant nests on plant associations were unknown for many species. The Brazilian savanna weaver ant was recorded on 17 plant species belonging to 11 families. Their field survey recorded nine plant species in eight families at Brazilian closed areas. Overall, they expanded up to 24 host plant species and 14 families, including economically important tree species such as mango, citrus and jambo trees. Keeping in mind the importance of management of major pests of fruit crops and the successful use of *O. smaragdina* as a potential biocontrol agent worldwide, present investigation was initiated with the objective to study the colony inhabitation of Weaver ant, *O. smaragdina* in different plant hosts and their impact on the yields of selected horticultural crops.

Materials and Methods

Colony inhabitation in different plant hosts

Survey was conducted to know the colony inhabitation of *Oecophylla smaragdina* in different plant hosts at Annamalainagar by all-out search method. Each of the trees/plants in the study site was surveyed for the presence of ants, in the following sequence. Firstly, the trunk and lower branches (in case of trees) and whole plant (in case of shrubs) were examined for ant trails. If no ants were found, binoculars were used to scan the canopy for trails and nests. The presence of nests alone was never accepted as proof of ant presence, as nests were often abandoned in seemingly healthy condition during colony contraction periods. Some large trees had dense foliage that obstructed observation. For these an unskilled labour climbed into the canopy to look for ants. Using this combination of techniques, quite small populations could be detected, trees/plants with ant nest and without ant nest were noted. Identification of plant hosts were done at species level. Surveys were conducted from March 2017 - February 2018 at monthly intervals.

Impact on arthropods

Five mango trees with and without ant nests were selected in the orchard of Faculty of Agriculture, Annamalai University, Annamalainagar. Hundred leaves were collected from each tree. The leaves along with arthropods were collected from four zones within the tree- low outer canopy, mid outer canopy, top outer canopy and inside the canopy. In each zone, leaves were taken from randomly selected angles and put into a polythene bag and taken to the laboratory. Arthropods separated from leaf samples were killed and mounted for identification up to species level and their numbers were also recorded. Leaf samples were collected during the months of February, April, July, August, September, December of 2017 and February 2018.

Impact on the yield

The impact of *Oecophylla smaragdina* on the yields of *Mangifera indica*, *Manilkara zapota*, *Citrus limon* in the orchard of Faculty of Agriculture, Annamalai University, Annamalainagar and *Anacardium occidentale* in the farmer's

field at Kodukkanpalayam were assessed in randomly selected tree pairs (with ant nest and without ant nest) during April 2017- August 2017. Yield of fruits of five trees with and without ants in each of *Mangifera indica*, *Manilkara zapota*, *Citrus limon* and *Anacardium occidentale* were recorded.

Results and Discussion

Colony inhabitation in different plant hosts

This is the maiden attempt to record the plant hosts of *Oecophylla smaragdina* in Cuddalore district, Tamilnadu. New record of a creeper plant host, *Coccinia indica* was recorded from India.

Survey results on the colony inhabitation of *O. smaragdina* in different plant hosts during March 2017-February 2018 at Annamalainagar are listed in Table 1. Seventeen hosts under fourteen families *viz.,* Annonaceae, Meliaceae, Myrtaceae, Fabaceae, Rubiaceae, Moraceae, Rosaceae, Anacardiaceae, Sapotaceae, Poaceae, Malvaceae, Rutaceae, Lecythidaceae, *Cucurbitaceae* and one unidentified hosts were recorded for the presence of *O. smaragdina*. Fifty four plants devoid of *O. smaragdina* were also identified and listed in Annexure I. Colony inhabitation of *O. smaragdina* occurred in *Mangifera indica* as highest for all the twelve months. In *Morinda citrifolia*, *Manilkora zapota*, *Prunus dulcis, Citrus limon* months of occupancy of *O. smaragdina* were ten, nine, eight and six respectively.

In *Azadiracta indica* and *Ixora coccinea* occupancy periods by *O. smaragdina* was four months (March- June). *Pongamia Pinnata, Ficus carica*, *Kinabaluchloa nebulosa* and unidentified species were inhabited by *O. smaragdina* for two months (March – April). *Thespesia populnea*, *Couroupita guianensis*, *Coccinia indicia, Cassia fistula* were occupied as lowest for a month alone during September; October respectively by *O. smaragdina* (Table 1).

Oecophylla smaragdina found maximum in March and April months in most of the host plants (13 numbers) as they were in flowering and flushing of new leaves. Abiotic factors like temperature and rainfall were favorable for *O. smaragdina* colony inhabitation and also homopteran population was high.

Similar to present study results Lach *et al.* (2010) also stated that *O. smaragdina* inhabitation was present in cashew, citrus, cocoa, coconut, mango and oil palm. Lokkers (1990) reported that maximum number of *O. smaragdina* inhabited trees of *Zizyphus mauritiana* occurred in May. Similarly the peak number of *Lophostemon grandiflorus* trees occupied in March and peak habitation of *Melaleuca* trees coincided in March. Occupancy levels of *Pongamia pinnata*, however, were low when they flowered from September to November, because these deciduous trees were bar of leaves during this period. This is in accordance with present study results in which also few host plants were occupied only for least periods (1-2 months) because of falling of leaves and low canopy density.

Impact on arthropods

The studies conducted on impact of *Oecophylla smaragdina* on arthropods on leaf samples in *Mangifera indica* are mentioned in Table 2. Among the collected arthropods the number of *Apoderus tranquebarious* were 0.79 in trees with ant nest and 1.29 in trees without ant nest followed by *Estenorhinus sp.* as 0.29 in trees with ant nest and as 1.42 in trees without ant nest followed by *Orthaga euadrusalis* as 0.72 in trees with ant nest and as 1.19 in trees without ant nest and *Dysdercus cingulatus* as 0.58 in trees with ant nest and as 1.56 in trees without ant nest. *Hippasa sp.*were recorded as 0.02 in trees with ant nest and as 0.10 in trees without ant nest and *Aulacaspis tubercularis* were recorded as 54.02 in trees with ant nest and as 56.32 in trees without ant nest. *Drosicha mangiferae* were noticed as 43.26 in trees with ant nest and as 45.51 in trees without ant nest and number of *Idioscopus nitidulus* were found as 8.58 in trees with ant nest and as 11.26 in trees without ant nest (Table 2).

The present study results, showed that, trees with ant nest had lowest number of arthropods than trees without ant. Mostly Coleopterans and Lepidopterans were well reduced by *O. smaragdina* in trees with ant nests. But Homopteran levels were highest than other arthropods in trees with ant nest as they serve their energy needs.

Partially similar to present study results Way (1954) also recorded that increased abundances of the *Diaspids Aspidiotus* destructor, *Hemiberlesia latinae*, and *Phenacaspis inday* in coconut trees inhabited by *O. longinoda*, presumably due to incidental protection from predators or parasites. Fowler and Mac Garvin (1985) attributed increased numbers of leaf-miners in ant-occupied birch trees to removal of competitors or predators by ants. Ants can thus cause detrimental effects to trees by incidentally protecting untended insects, as well as by encouraging and protecting honeydew-producing homopterans.

Lokkers (1990) defined the green tree ants reduced numbers of both herbivores (e.g. beetles) and predators (e,g. beetles) and predators (e.g. spiders). Laine and Niemela (1980) observed reduced spider densities in birch trees near *Formica aquilona* nests. They offered 2 plausible processes for this effect: competitive exclusion by the reduction of available prey, and direct predation of spiders by ants.

Mahapatro and Mathew (2016) found parasitized scales on trees with ants depicting that ants are not antagonist to parasitoids of coccids even inside the enclosed nests.

The mango seed weevil, *Cryptorhynchus mangifera,* can destroy large proportions of seeds without any outward evidence of attack (Simpson, 1995). Friederichs (1920) reported that *O. smaragdina* reduced weevil damage in mango fruit in Java. These ants might deter adult weevils from depositing eggs on the young fruit. This is in accordance with present study results.

Circadian activity patterns may also influence the impact of ants on arthropod fauna. *O. smaragdina* returned with prey mainly during daylight hours; this trend has also been observed in wood ants (e.g. Skinner, 1980; Rosengren and Sundstrom, 1987), and is probably due to these species reliance on vision for hunting. Many leaf-chewing insects in forests are active at night (Windsor, 1978), and would thus be less susceptible to predation by diurnal predators such as *O. smaragdina.*

According to Dejean (1991), an ant colony with 12 nests (*Oeophylla spp.* colonies are polydomous) can capture 45,000 prey items per year. The two species of weaver ants (*O. smaragdina* and *O. longinoda*) are effective biological control agents against more than 50 different pests in many

tropical crops and forest trees (Way and Khoo, 1992; Peng *et al*., 1995). *Oecophylla* ants can be equally more effective than chemical pesticides (Peng and Chiristian, 2005; Dwomoh *et al.,* 2009; Offenberg *et al*., 2013). The effectiveness of weaver ants in controlling pests positively, correlated with ant abundance on their host trees. These studies are in confirmation with the present study results.

Similar to present findings Peng *et al*. (2008) stated that weaver ant colonies must be managed to keep abundance high and in this way obtain effect control of pests. It is generally believed that trees are well protected against insect pests if more than 50% of trees main branches hold weaver ant trails. Therefore the weaver ant abundance is an important factor which must be monitored frequently to gain maximum profit from the presence of ants.

According to Lach *et al.* (2010), >50 species of hemipteran bugs, beetles, fruitflies, caterpillars, thrips, pest ants, and leafhoppers were controlled by *O. smaragdina* which is similar to the present study results.

Impact on the yield

The impact of *O. smaragdina* on fruit production of *Mangifera indica*, *Manilkara sapota* and *Citrus limon* at Annamalainagar and *Anacardium ocidentale* in Kodukanpalayam during April to August 2017 is presented in the Table 3. The yields of *Mangifera indica*, *Manilkara sapota*, *Citrus limon* and *Anacardium occidentale* were 43.64, 73.16, 1.00 and 22.28 Kgs per tree respectively in the presence of *O. smaragdina* nests whereas in trees without ant nests the yields were 36.08, 65.28, 0.80 and 19.60 Kgs per tree respectively.

From the present findings it is clear that trees with *O. smaragdina* nests produced more fruits than trees without ant nests. *Manilkara zapota* yielded more than *Mangifera indica* in which number of green nests were more during the study period. Also *Anacardium occidentale* recorded more yield than *Citrus limon* in which ant nests were present throughout the year (as recorded by farmer).

Rickon and Rickson (1998) stated that cashew trees are consistently ant visited throughout the year, with ants attracted to large number of extra floral nectarines on leaves, infloresences, flowers and developing nuts. The commercial plantation in India, Brazil, and east Africa, consistently applies pesticides in large monoculture plantings. Each year prophylactic spraying begins with the first flush of new leaves. Continues through flowering, ending at about mid-nut development. Extensive survey depicts the ant –cashew relationship showing the potential of ants replacing pesticides in insect control. This is in confirmation with the present study results.

Conservation by biological control with predatory ants such as *O.smaragdina* in high value tree crops has great potential for African and Asian farmers (Van Mele *et al*., 2007). This supports the present study results. Experiment conducted by Adandonona *et al*. (2009), shown that the fruit flies *Bactrocera invadens* and *Ceratitis cosyra* is significantly reduced in mango trees with weaver ants, but they rarely observed adult flies being captured and they also investigated whether *Oecophylla* pheromones affect fruitfly oviposition behaviour on host. Mangoes were collected within 1 m and 1–3 m distance from ant nests, and from ant-free trees. Using both choice and no-choice tests, fruit flies were allowed to oviposit on fruits for 72 h in the absence of ants. Flies landed significantly more and spent more time on fruit from ant-free than from ant-colonized trees.

Present findings are in line with Peng *et al*. (2013) whom stated that *Oecophylla* ants, predated on immature stages and exhibit physical deterrence on adults, able to control all major pests, including shoot borers *Hypsipyla robusta*, fruit spotting bugs *Amblypelta lutescens*, yellow loopers, *Gymneosceli sp.* and bush crickets, *Myara yabmanna*. Also studies by Mahapatro and Mathew (2016) on *O. smaragdina* proven for its potential as a predator in Kerala conditions. Cashew being a premium commodity, organic cashew would catch up well, and "ant technology" can very well serve as an ideal role. Cashew trees with ant nests may be spared of spraying to facilitate reduction in pesticide – load in the environment, a definite input use efficient tactic. They also inferred that ants may not be a threat in terms mutual symbiotic association with homopteran insect–pests (trophobionts) which of course needs further confirmation. If the state of the art is standardized in ant technology in cashew, and validated properly in Indian context, this may solve the greatest pest problem of cashew cultivation in India and other Cashew growing countries, and maintain a clean environment. This is supportive to the present findings.

Aidoo (2009) claimed that management with weaver ants was cheaper than applying chemicals as net returns increased. Lokkers (1990) concluded from a commercial viewpoint, that removal of *O. smaragdina* from mango trees may improve mango crop yields, but may increase frugivory by fruit bats. Ants might become more beneficial if levels of herbivory rose. An outbreak of herbivorous insects, could be reduced by *O. smaragdina*. However, the increased homopteran abundance (both tended and untended) in trees occupied by *O. smaragdina* is a disadvantage which needs to be carefully weighed against possible benefits to any commercial crops. This is in accordance with the present study results.

Table 1 : Colony inhabitation of *Oecophylla smaragdina* in different plant hosts (March 2017- February 2018)

S. No	Trees /plant host Family	Trees /plant host Species	Presence of *Oecophylla smaragdina*											
			Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1.	Annonaceae	*Polyalthia longifolia*	+	+	+	-	-	-	-	-	-	-	-	-
2.	Meliaceae	*Azadiracta indica*	+	+	+	+	-	-	-	-	-	-	-	-
3.	Myrtaceae	*Psidium guajava*	+	+	+	-	-	-	-	-	-	-	-	-
4.	Fabaceae	*Pongamia Pinnata*	+	+	-	-	-	-	-	-	-	-	-	-
5.	Rubiaceae	*Ixora coccinea*	+	+	+	+	-	-	-	-	-	-	-	-
6.	Moraceae	*Ficus carica*	+	+	-	-	-	-	-	-	-	-	-	-
7.	Rosaceae	*Prunus dulcis*	+	+	+	+	+	-	-	-	+	-	+	+
8.	Anacardiaceae	*Mangifera Indica*	+	+	+	+	+	+	+	+	+	+	+	+

9.	Sapotaceae	*Manilkara Zapota*	+	+	-	-	+	+	+	+	+	-	+	+
10.	Rubiaceae	*Morinda citrifolia*	+	+	+	+	+	+	+	+	-	-	+	+
11.	Poaceae	*Kinabaluchloa nebulosa*	+	+	-	-	-	-	-	-	-	-	-	-
12.	Malvaceae	*Hibiscus rosa sinensis*	-	-	-	-	-	-	-	+	+	-	-	-
13.	Rutaceae	*Citrus limon*	+	+	-	-	-	+	+	+	-	-	-	+
14.	Malvaceae	*Thespesia populnea*	-	-	-	-	-	-	+	-	-	-	-	-
15.	Lecythidaceae	*Couroupita guianensis*	-	-	-	-	-	-	+	-	-	-	-	-
16.	Fabaceae	*Cassia fistula*	-	-	-	-	-	-	-	+	-	-	-	-
17.	Cucurbitaceae	*Coccinia indica*	-	-	-	-	-	-	+	-	-	-	-	-
18.	Unidentified	Unidentified	+	+	-	-	-	-	-	-	-	-	-	-

+ : Presence of *Oecophylla smaragdina* - : Absence of *Oecophylla smaragdina*

Table 2 : Impact of *Oecophylla smaragdina* on arthropods on leaf samples in *Mangifera indica* at Annamalainagar

S.No	Name of the arthropod	Scientific name	Family	Order	Number of arthropods	
					Trees with ant nest*	Trees without ant nest*
1.	Red bugs	*Dysdercus cingulatus*	Pyrrhocoridae	Heteroptera	0.58	1.56
2.	Leaf twisting weevil	*Apoderus tranquebarious*	Curculionidae	Coleoptera	0.79	1.29
3.	Brentid beetle	*Estenorhinus sp.*	Brentidae	Coleoptera	0.29	1.42
4.	Mango leaf webber larvae	*Orthaga euadrusalis*	Pyralidae	Lepidoptera	0.72	1.19
5.	Mango flower webber	*Eublemma versicolor*	Noctuidae	Lepidoptera	0.26	0.78
6.	Mango shoot webber	*Orthaga exvinacea*	Pyralidae	Lepidoptera	0.18	0.43
7.	Mango leaf hopper	*Idioscopus nitidulus*	Cicadellidae	Hemiptera	8.58	11.26
8.	Mango mealy bug	*Drosicha mangiferae*	Pseudococcidae	Hemiptera	43.26	45.51
9.	Mango scales	*Aulacaspis tubercularis*	Diaspididae	Hemiptera	54.02	56.32
10.	Spider	*Hippasa sp.*	Lycosidae	Araneae	0.02	0.10

*Mean of 100 leaves

Table 3: Impact of *Oecophylla smaragdina* on the yields of selected horticultural crops (April 2017- August 2017)

Host trees	Yield (Kgs) #*	
	Trees with ant nest	Trees without ant nest
Mangifera indica	43.64	36.08
Manilkara zapota	73.16	65.28
Citrus limon	1.00	0.80
Anacardium occidentale	22.28	19.60

#- Mean of five months *-Mean of five trees

Annexure-I

Trees devoid of *Oecophylla smaragdina* at Annamalainagar

S. No	Common name	Family	Scientific name
1.	Banyan tree	Moraceae	*Ficus benghalensis*
2.	Tamarind tree	Fabaceae	*Tamarindus indica*
3.	Gulmuhar tree	Caesalpiniaceae	*Delonix regia*
4.	Camel food tree	Fabaceae	*Phanera purpurea*
5.	Subabul tree	Fabaceae	*Leucaena leucocephala*
6.	Acacia tree	Fabaceae	*Acacia concinna,*
7.	Peepal tree	Moraceae	*Ficus religiosa*
8.	Teak	Lamiaceae	Tectona grandis
9.	Sal tree	Dipterocarpaceae	*Shorea robusta*
10.	Eucalyptus tree	Myrtaceae	*Eucalyptus globules*
11.	Cassurina tree	Casuarinaceae	*Casuarina equisetifolia*
12.	Indian mahogany	Meliaceae	*Swietenia mahagoni*
13.	Malai vembu tree	Meliaceae	Melia dubia
14.	Mahua tree	Sapotaceae	*Mahua longifolia*
15.	Carry tree	Rutaceae	*Murraya koenigii)*
16.	Pi –Nari maram tree	Simaroubaceae	*Ailanthus excelsa,*
17.	Papaya	Caricaceae	*Carica papaya,*
18.	Arjuna tree	Combretaceae	*Terminalia arjuna*
19.	Vanni- anadra tree	Fabaceae	*Prosopis cineraria*

20.	Palmyra tree	Arecaceae	*Borassus flabellifer*
21.	Amla tree	Phyllanthaceae	*Phyllanthus emblica,*
22.	Goose berry	Phyllanthaceae	*Phyllanthus acidus,*
23.	Coconut	Arecaceae	*Cocos nucifera*
24.	Indian bael	Rutaceae	*Aegle marmelos*
25.	Jackfruit tree	Moraceae	*Artocarpus heterophyllus*

Shrubs devoid of *Oecophylla smaragdina* at Annamalainagar

S. No	Common name	Family	Scientific name
26.	Crape jasmine/Carnation of India	Apocynaceae	*Tabernaemontana divaricata*
27.	Globe amaranth	Amaranthaceae	*Gomphrena globosa*
28.	Sunflower	Astraceae	*Helianthus annus*
29.	Mustard	Brassicaceae	*Brassica juncea*
30.	Frangipani	Apocynaceae	*Plumeria alba*
31.	Elephant –ear	Araceae	*Colacasia esculenda*
32.	Dhaincha	Fabaceae	*Sesbania bispinosa*
33.	Pomegranate	Lythraceae	*Punica granatum*
34.	Glorybower	Lamiaceae	Clerodendrum bungei
35.	Bitter Cassava	Euphorbiaceae	*Manihot esculenta*
36.	Castor-oil-plant	Euphorbiaceae	*Ricinus communis*
37.	Indian mallow	Malvaceae	*Abutilon indicum*
38.	Ladies fingers	Malvaceae	*Abelmoschus esculentus*
39.	Cotton	Malvaceae	*Gossypium hirsutum*
40.	Rose	Rosaceae	*Rosa berberifolia*
41.	Curry leaf	Rutaceae	*Murraya koenigii*
42.	Purble fruited pea eggplant	Solanaceae	*Solanum trilopatum*
43.	Brinjal	Solanaceae	*Solanum melangena*
44.	Black night shade/Wonder berry	Solanaceae	*Solanum torvum*
45.	Tomato	Solanaceae	*Lycopersican esculentum*
46.	Lantanas/ shrub verbenas	Verbenaceae	*Lantana camera*

Creepers devoid of *Oecophylla smaragdina* at Annamalainagar

S. No	Common name	Family	Scientific name
47.	Money plant	Araceae	*Sciendapus aureus*
48.	The field bind weed	Convolvulaceae	*Convolvulus arvensis*
49.	Bitter gourd	Cucurbitaceae	*Momordica charantia*
50.	Ivy gourd	Cucurbitaceae	*Coccinia grandis*
51.	Pumpkin	Cucurbitaceae	*Cucurbita pepo*
52.	Sponge gourd	Cucurbitaceae	*Luffa aegyptiaca*
53.	Ridged gourd	Cucurbitaceae	*Luffa acutangula*
54.	Water melon	Cucurbitaceae	*Citrullus lanatus*

References

Adandonon, A.; Vayssières, J.F.; Sinzogan, A. and Van Mele, P. (2009). Density of pheromone sources of the weaver ant *Oecophylla longinoda* affects oviposition behaviour and damage by mango fruit flies (Diptera: Tephritidae). International Journal of Pest Management, 55(4): 285-292.

Aidoo, K.S. (2009). Boosting cashew production in Ghana. Bees for Development, 91(3): 8-9.

Azuma, N.; Ogata, K.; Kikuchi, T. and Higashi, S. (2006). Phylogeography of Asian weaver ants, *Oecophylla smaragdina*. Ecological Research, 21(1): 126-136.

Dejean, A. (1991). Adaptation *d'Oecophylla longinoda* aux variations spatio-temporelles de la densité en proies. Entomophaga, 36(1): 29– 54.

Dwomoh, E.A.; Afun, J.V.K.; Ackonor, J.B. and Agene, V.N. (2009). Investigations on *Oecophylla longinoda* (Latreille) (Hymenoptera: Formicidae) as bio control agents in the protection of cashew plantations. Pest Management sciences, 65: 41–46.

Fowler, S.V. and Mac Garvin, M. (1985). The impact of hairy wood ants *Formica lugubris* on the guild structure of herbivorous insects on birch *Betula pubescens*. Journal of animal ecology, 54: 847-855.

Friederichs, K. (1920). Weberameisen und pflanzenschutz . Tropenflanzer, 23: 142-150.

Lach, L.; Parr, C. and Abbott, K. (2010). Ant ecology. Oxford University Press.

Laine, K.J. and Niemela, P. (1980). The influenze of ants on the survival of mountain birches during an *Opornia autumnata* outbreak. Oecologia, 47: 39-42.

Lim, G.T.; Kirton, L.G.; Salom, S.M.; Kok, L.T.; Fell, R.D. and Pfeiffer, D.G. (2008). Host plants and associated trophobionts of the weaver ants *Oecophylla spp*. (Hymenoptera: Formicidae). CAB Reviews: Perspectives in Agriculture, Veterinary Science,

Nutrition and Natural Resources 3: No. 035, CABI, Wallingford.

Lokkers, C. (1990). Colony dynamics of the Green Tree Ant, (*Oecophylla smaragdina* Fab) in a seasonal tropical climate, Ph.D. thesis. James Cook University of North Queenslade. 322.

Mahapatro, G.K. and Mathew, J. (2016). Role of Red-Ant, *Oecophylla smaragdina* Fabricius (Formicidae: Hymenoptera) in Managing Tea Mosquito Bug, *Helopeltis* species (Miridae: Hemiptera) in Cashew. Biological Science, 86(2): 497–504

Offenberg, J.; Cuc, N.T.T. and Wiwatwitaya, D. (2013). The effectiveness of weaver ant (*Oecophylla smaragdina*) biocontrol in Southeast Asian citrus and mango. Asian Myrmecology, 5: 139-149.

Peng, R.K. and Christian, K. (2005). Integrated pest management in mango orchards in the Northern Territory Australia, using the weaver ant, *Oecophylla smaragdina*, (Hymenoptera: Formicidae) as a key element. International Journal of Pest Management, 51(2): 149-155.

Peng, R.K.; Christian, K. and Gibb, K. (1995). The effect of the green ant, *Oecophylla smaragdina* (Hymenoptera: Formicidae), on insect pests of cashew trees in Australia. Bulletin of Entomological Research, 85(2): 279-284.

Peng, R.K.; Christian, K.; Lan, L.P. and Binh, N.T. (2008). Integrated cashew improvement program using weaver ants as a major component. Manual for ICI program trainers and extension officers in Vietnam. Charles Darwin University and Institute of Agricultural science for South Vietnam, 93.

Peng, R.; Christian, K. and Reilly, D. (2013). Using weaver ants *Oecophylla smaragdina* to control two important pests on African mahogany *Khaya senegalensis* in the Northern Territory of Australia. Australian forestry, 76(2): 76-82.

Rickson, F.R. and Rickson, M.M. (1998). The cashew nut, *Anacardium occidentale* (Anacardiaceae), and its perennial association with ants: extrafloral nectary location and the potential for ant defense. American Journal of Botony, 85: 835–849.

Rosengram, R. and Sundstrom, L. (1987). The foraging system of a red wood ant colony- collecting and defending food through an extended phenotype. Experimental Supplimentary, 54: 117- 137.

Santos, J.C.; Aguiar, J.J.M.; Alves, T.R.; Almeida, W.R. and Del-Claro, K. (2016). New records of host plants used by a weaver ants *Camponotus textor* Forel, 1899 (Hymenoptera: Formicidae). JEAP, 1(1): 111-116.

Simpson, G.B. (1995). The biology and field control of the mango seed weevil *Cryptorhynchus mangiferae*. In processing 1st Australian Mango research workshop, CSIRO. Melbourne.

Skinner, G.J. (1980). The feeding habits of the wood ant, Formica rufa, in limestone woodland in NW England. Journal of animal Ecology, 49: 417-433.

Van Mele, P.; Vayssières, J.F.; Van Tellingen, E. and Vrolijks, J. (2007). Effects of an African weaver ant, *Oecophylla longinoda*, in controlling mango fruit flies (Diptera: Tephritidae) in Benin. Journal of Economic Entomology, 100(3): 695-701.

Way, M.J. (1954). Studies of the life history and ecology of the ant *Oecophylla longinoda* Latreille. Bulletin of Entomological Research, 45(1):93-112.

Way, M.J. and Khoo, K.C. (1992). Role of ants in pest management. Annual Review of Entomology, 37: 479 – 503.

Windser, D.M. (1978). The feeding activities of tropical insect herbivores on some deciduous forest legumes. Montgomery, G.G. (Eds.), The ecology of arboreal folivores. Smithsonian press. Washington. 16(3): 101 – 114.